Design and performance of an integrated ground and space sensor web for monitoring active volcanoes

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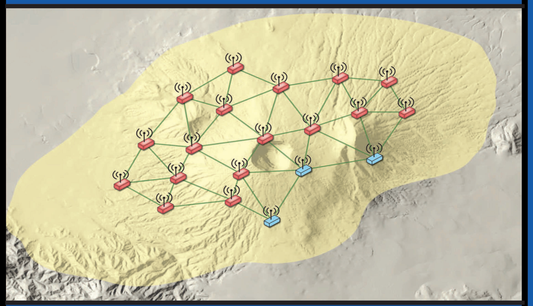
Abstract

An interdisciplinary team of computer, earth and space scientists collaborated to develop a sensor web system for rapid deployment at active volcanoes.

The primary goals of this Optimized Autonomous Space In situ Sensorweb (OASIS) are to:
1) integrate complementary space and new ground-based elements into an interactive, autonomous sensor web;
2) advance sensor web power and communication resource management technology; and
3) enable scalability for seamless addition sensors and other satellites into the sensor web.

This three-year project began with a rigorous multidisciplinary interchange that resulted in definition of system requirements to guide the design of the OASIS network and to achieve the stated project goals. Based on those guidelines, we have developed fully self-contained in situ nodes that integrate GPS, seismic, infrasonic and lightning (ash) detection sensors. The nodes in the wireless sensor network are linked to the ground control center through a mesh network that is highly optimized for remote geophysical monitoring. OASIS also features an autonomous bidirectional interaction between ground nodes and instruments on the EO-1 space platform through continuous analysis and messaging capabilities at the command and control center. Data from both the in situ sensors and satellite-borne hyperspectral imaging sensors stream into a common database for real-time visualization and analysis by earth scientists.

Sensorweb

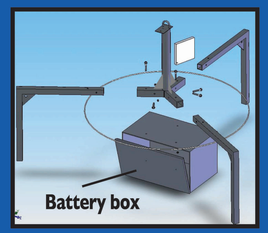


We have successfully completed a field deployment of 15 nodes within the crater and on the flanks of Mount St. Helens, Washington. The demonstration that sensor web technology facilitates rapid network deployments and that we can achieve real-time continuous data acquisition. We are now optimizing component performance and improving user interaction for additional deployments at erupting volcanoes in 2010.

Ground Nodes - "Smart" spiders/software

Features:

- Fully self-contained package
- Batteries for one year without recharge
- Rapidly set in place via helicopter sling with remote release
- Self-forming self-healing mesh network
- Routing optimized for many nodes to single gateway
- In-situ data analysis and Dynamic QoS service based on scientific priority of data (V-FWQ)
- Analog, digital and serial interfaces for sensors including:
  - Rugged seismic accelerometer
  - GPS for sub-cm deformation monitoring and millisecond timing
  - Infrasonic micro-barometer for explosion detection
  - Lightning detector for severe ash cloud detection



Portable Spider Package

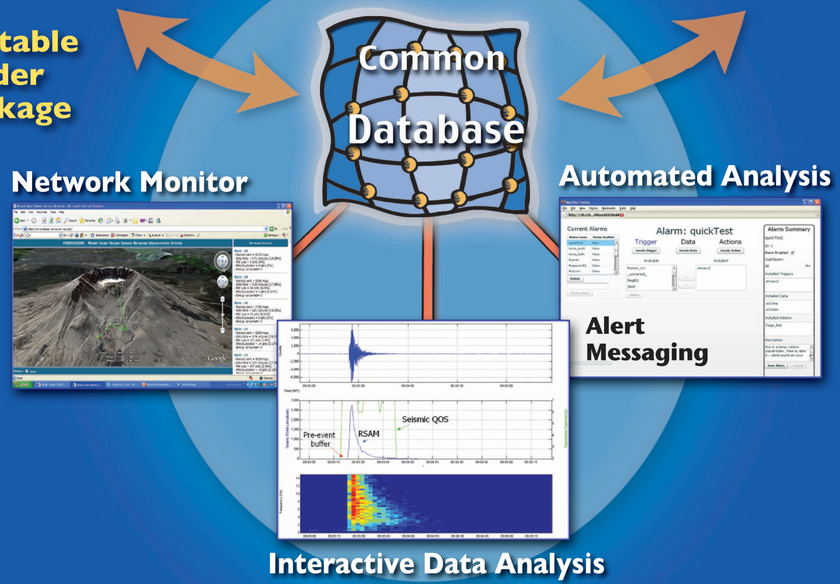
Spider ready for deployment at Mount St. Helens

Command and Control Center

Features:

- Data Ingestion and Storage
- Data Visualization and Analysis:
  - VALARM
  - VALVE
  - WINSTON
  - Earthworm
  - Network Monitor and Prioritization Management
- Scientific Alert Service
- Autonomous Interface
  - Ground-to-Space and Space-to-Ground

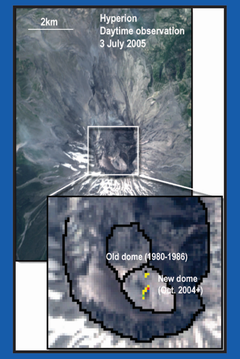
Operations Center Software



Space Component EO1+ Software

Features:

- Earth Observing -1 satellite
- Hyperion hyperspectral VIS-SWIR imager with 220 bands at 30mresolution
- Autonomous onboard data processing of Hyperion data enables:
  - Thermal products are abstracted onboard and efficiently downloaded
  - Compressed images of interest are generated with fast delivery
  - Requests for sensorweb response are autonomously generated

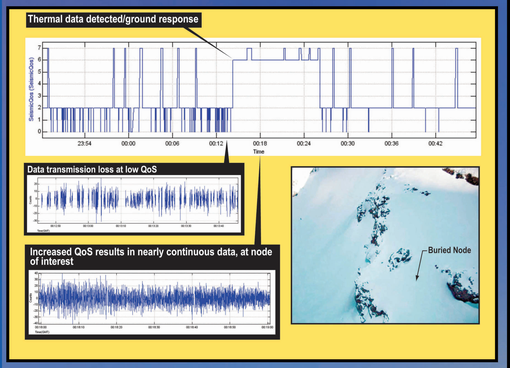


Results of onboard hyperspectral processing to generate thermal summary.

Performance - Deployment at MSH

Results of Triggered End-to-End Test

Data autonomously delivered to Ground System and ingested into time-series data base. VAlarm detects new data and triggers autonomous ground response through Command and Control: heighten priority (QoS) of crater node (node 4 under snow) seismic data.



Location of Spiders